Development and Testing of a Cost-Allocation-Based Cost-Estimating Method

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The status of the development of a transit operating cost model for the Financial Analysis Portion of the Corridor Refinement Study currently being undertaken for the Metropolitan Transit Authority of Harris County, the public transit operator in the Houston, Texas, region, is described. The approach used to develop the cost model and a recent application in financial analysis in Houston are detailed.

The development of a transit operating cost model is part of a continuing transit planning effort following the original Transitway Alternatives Analysis Study begun in 1979 for the Metropolitan Transit Authority (MTA) of Harris County, the public transit operator in the Houston, Texas, region. To date, the study has identified a priority corridor and has begun preliminary engineering and financing for rail rapid transit and busways in that corridor. In addition, a regionwide program of bus service expansion, feeder bus routes, and development of other busways with the Texas State Department of Highways and Public Transportation is being considered.

The financial analysis will integrate all estimates--operating and capital expenses as well as projected operating revenues and local sales tax, state, and federal funding. The operating cost model will project the costs for all expense portions of the operating budget--wages, salaries, fringe benefits, parts, diesel fuel, electricity, claims, insurance, and taxes.

The cost model is structured around a carefully defined set of assumptions regarding the transit technologies used and institutional and administrative considerations. The fundamental consideration was that both bus and rail operations and maintenance activities would be handled by MTA.

The cost model is structured in such a way that, once annual bus and rail operating statistics have been determined, the annual costs can be quickly computed. The primary input to the bus and rail models, traditionally developed in the urban transportation planning process, include peak vehicles, annual vehicle hours, and annual vehicle miles. In addition, the rail model requires descriptors of the physical characteristics of the system including stations, route miles, and yards.

The cost models are intended to be used in evaluating alternative regional bus and rail transit systems. The computerized version projects costs in both base year (1982) and inflated dollars.

APPROACH

This operating cost model was built on the original cost model developed by Peat Marwick for the Houston Transitway Alternatives Analysis (1) and later expanded and refined for the following studies: Washington Metropolitan Area Transit Authority (WMATA) FY80 Net Income Analysis (2), New Orleans Cable-Suspended Transit System Study (3), St. Louis Light Rail Study (4), and Detroit Woodward Corridor Light Rail Transit Study (5).

The cost model, built on this experience and described in this paper, adds several improvements that make the model suitable for both short-range budget analysis and long-range system planning.

1. Costs modeled by responsibility center. To structure the model with a minimum of preliminary data preparation, the fundamental administrative units modeled were the responsibility centers defined by the MTA Office of Budget Systems. Budget information was the major source for data; this proved a convenient way to arrange costs. For each responsibility center, the budget identified the costs for union wages, nonunion salaries, and major categories of direct costs. A determination was made for each responsibility center--whether the costs were fixed, related indirectly to some measure of system size, related indirectly to overall growth in service, or required modeling of specific labor categories.

2. Costs modeled for each union position. Recognizing that union labor costs account for approximately one-half of total transit costs, the cost model was structured so that each union position was modeled. The number of employees in each position was made a function of a specific measure of system size or quantity of service provided. Average annual wages were then applied.

3. Costs modeled for each front-line supervisory position. The salaries for each front-line supervisor (foreman, street supervisor, etc.) for the union positions were also separately modeled. Generally, the costs were computed for staffing levels (number of union employees for each front-line supervisor) or shift coverage.

4. Electricity costs modeled according to utility rate structure. The costs for traction, yard, station, and chiller plant electricity were modeled on the Houston Lighting and Power Company rate structure for Large General Service (LGS). The rate structure was applied assuming all connected loads were through the traction power substations.

5. Rail operations costs based on system operating plan. The designers of the rail system, Houston Transit Consultants, provided a staffing plan and organizational structure for developing cost equations for the rail operations.

The cost model is composed of a series of equations that project costs as a function of the quantity of service provided. Costs were computed for each responsibility center, union position, front-line supervisory position, and major type of direct cost. Specific costs were identified as either fixed or variable, driven by specific descriptors of service or physical characteristics of the system. Figure 1 presents the system characteristics used to drive the costs.

The cost equations were organized generally around the current MTA management structure assuming that, in the case of the rail alternatives, a separate Rail Operations Division, parallel with the Bus Operations Division, would be created. Figures 2, 3, and 4 present a list of the equations used in the cost model. Figure 5 presents an example of the worksheets used to manually compute the costs. It presents the various cost factors, their values, and data sources. Worksheets such as these were used to formulate the model, create computer code, and check the computer-derived cost projections. A complete description of the equations, including values and sources of information for each cost factor, is documented in various study working papers (6).

INFLATION CONSIDERATIONS

All of the unit cost values in the operating cost models are in 1982 dollars. They are based on either current (1982) experience or are historical unit costs inflated to 1982 dollars. These unit costs will be used in the financial analysis to project future costs. Operating costs will be presented in both future-year dollars and in 1982 dollars.

Data Resources, Inc. (DRI), prepared the following four series of inflation projections for MTA:

1. Houston consumer price index (CPI)--the "baseline" rate of inflation, against which all other inflation projections were compared. It was assumed that wages and salaries inflate at this rate (thus, there was no "real" rate of inflation for wages and salaries).
2. U.S. average CPI--the assumed rate of inflation for other direct costs and insurance. Insurance costs could inflate at a substantially higher rate as the insurance market becomes less "soft" as a result of lower interest rates.
3. Houston diesel fuel--the rate for MTA bus diesel fuel was assumed to be equal to the rate for the Houston region. The projection considered price, demand, and availability.
4. Houston electricity--the rate for HL&P industrial customers.

Figure 1. Driving variables.

BUS SYSTEM CHARACTERISTICS

- Regular Buses: standard 40-foot coaches required for peak-period schedule service. Includes current GMC "New Look," RTS-II, RTS-04, Grumman 870, and Eagle coaches.
- Articulated Buses: Sixty-foot M.A.N. -AM General articulated coaches or equivalents, required for peak period scheduled service.
- Regular Bus Surface Street Miles: annual miles travelled by regular buses on surface streets (as coded in the transit network).
- Articulated Bus Surface Street Miles: annual miles travelled by articulated buses on surface streets (as coded in the transit network.)
- Articulated Bus Guideway Miles: annual miles travelled by articulated buses on guideways (as coded in the transit network).
- Platform Hours: annual scheduled hours of service (including revenue, layover, and deadheading hours, factored on a system-wide basis).
- Operating Garages: operating bases from which scheduled buses are dispatched and where light routine maintenance and cleaning are performed.
- Sq. Feet Maintenance Facilities: floor area of offices, shops, and storerooms of operating garages and central shops.
- Park and Ride Lots: parking lots for both express buses and rail transit stations.
- Service Areas: districts defined for use in assigning street supervisors.
- Contra Flow Busways: the I-45 (North) Contra flow lane
- Gulf Freeway-Type Busways: one-way, reversible busways.
- Other Busways: priority-corridor, two-way busways. Busways from CBD to West Belt and from CBD to the North Corridor are considered separate busways.
- Total Revenue: fare box revenue for both bus and rail systems.

RAIL SYSTEM CHARACTERISTICS

- Peak Vehicles: vehicles required during peak period service.
- Base Trains: trains operated midday.
- Early/Late Trains: trains operating before the AM peak and after the PM peak.
- Total Vehicle Miles: annual vehicle-miles travelled in revenue service including deadheading.
- Route-Miles: double-track miles between station center lines on portions of the rail system in revenue service.
- Surface Stations: stations located at-grade or on elevated structures.
- Subway Stations: stations located below grade.
- Mezzanines: station entrances with a station agent and automated fare collection equipment.
- Service and Inspection (S&I) Yards: yards with storage capacity and service and inspection maintenance capability.
- Traction Substations: HL&P connection points where high voltage AC is converted to low voltage DC at MTA owned and operated facilities for use in powering trains.
- Chiller Plants: air conditioning units used to cool CBD stations and tunnels.
- Rail Passengers: annual rail passenger boardings.

Figure 2. Cost equations: bus operations.

DIRECTOR AND STAFF

- Assistant Executive Director and Staff
- Bus Operations Director and Staff
- Safety
  - Fixed
  - Quality Assurance Inspectors
  - Fluid Testing
- Labor Relations

VEHICLE MAINTENANCE

- Manager and Staff
- Garage Superintendents and Staff
  - Operating Buses
  - Central Shops
- Repairmen
  - Regular Buses
  - Articulated Buses
- Mechanical Foremen
- Service Attendants
- Custodians
- Cleaner Foremen
- Parts, Supplies, and Services
  - Regular Buses
  - Articulated Buses
- Diesel Fuel
  - Regular Buses
    - Surface Street Miles
    - Guideway Miles
  - Articulated Buses
  - Surface Street Miles
  - Guideway Miles
- Communications
  - Administration
  - Repairmen
  - Parts and Supplies
- Other Direct Costs

FACILITY MAINTENANCE

- Manager and Staff
- Building Maintenance
  - Superintendent and Staff
  - Repairmen
  - Cleaners
  - Direct Expenses
- Public Facilities
  - Administration
  - Sign and Shelter Repairmen
  - Park and Ride Lot Cleaners
  - Direct Expenses

TRANSPORTATION

- Manager and Staff
- Garage Superintendents and Staff
- Starters
- Scheduled Operators
- Extra Board Operators
- Operator Trainee Wages
- Road Operations Superintendents and Staff
- Street Supervisors
  - Base Service Areas
  - Expanded Service Areas
  - Busways

PLANNING AND SCHEDULING

- Manager and Staff
- Service Planning
- Telephone Information
- Scheduling
  - Supervisor and Staff
  - Schedule Makers
  - Traffic Checkers

EMPLOYEE DEVELOPMENT

- Manager and Staff
- Instructors

TRANSPORTATION PROGRAMS

- Manager and Staff
- Contra Flow
- Busways
  - Supervisors
  - Operations Deployment Personnel
  - Maintenance
  - Controllers
- Charter
- Car Share
- Metro Lift
- Para-Transit
  - Supervisors
  - Operators
  - Direct Expenses

GENERAL OPERATING COSTS

- Payroll Taxes - FICA
- Union Pension
- Life Insurance Plans
- Payroll Taxes - State Employment
- Workers Compensation Insurance
- Work Injury Payments
- Sick Leave
- Uniform and Tool Allowance
  - Maintenance
  - Transportation
- Longevity Award
- Benefit Trust Contribution
- Utilities
- Physical Damage Premium
- Casualty Claims Payments
- Workers Compensation Claims Payments
  - Operators
  - Maintenance
  - Administrative Employees
- Other Insurance Premiums
- Diesel Fuel Tax
- Gasoline Tax
- Rent
- Bodily Injury and Property Damage Insurance Premiums

Figure 3. Cost equations: rail operations.

DIRECTOR AND STAFF

- Director and Staff

TRANSPORATION

- Superintendent and Staff
- Central Control:
  - Assistant Superintendent and Staff
  - Supervisors
  - Controllers
    - Peak
    - Off-Peak
- Train Operations:
  - Assistant Superintendent and Staff
  - Supervisors
  - Train Operators
  - Yard Controllers
- Station Operations:
  - Assistant Superintendent and Staff
  - Station Agents
  - Supervisors

MAINTENANCE

- Superintendent and Staff
- Vehicle Maintenance:
  - Assistant Superintendent and Staff
  - Supervisors - Service and Inspection
    - S&I Repairmen
    - Car Cleaners
    - S&I Foremen
  - Supervisors - Component and Heavy Repair
    - Heavy Vehicle Repairmen
    - Heavy Repair Foremen
    - Component Repairmen
      - Vehicle
      - Wayside

MAINTENANCE (Con't)

      - Component Repair Foremen
    - Parts, Supplies, and Service
- Maintenance Control
  - Supervisor and Staff
  - Vehicle Repair Stores Clerk
  - Maintenance of Way Stores Clerk
  - Stores Foremen
  - Schedulers
- Maintenance of Way
  - Assistant Superintendent and Staff
  - Supervisor and Staff - Track and Structures
    - Building Maintainers
    - Station Janitors
    - Building and Structure Foremen
    - Track Maintainers
    - Track Foremen
    - Maintenance of Way Shop Repairmen
    - Maintenance of Way Shop Foremen
- Supervisor and Staff - Wayside Equipment
  - Train Control System Maintainers
  - Train Power System Maintainers
  - Communication Systems Maintainers
  - Fare Collection Equipment Maintainers
  - Wayside Equipment Foremen
- Parts, Supplies, and Services
  - Stations
  - Track and Structures
  - Train Control
  - Communications
  - Power
  - Fare Collection
- Electricity
  - Traction
  - Yards
  - At-Grade/Elevated Stations
  - Subway Stations
  - Chiller Plants

SAFETY AND ASSURANCE

- Superintendent and Staff
- Vehicle Inspectors
- Maintenance of Way Inspectors

GENERAL OPERATING EXPENSES

- Payroll Taxes - FICA
- Union Pension
- Life Insurance Plans
- Payroll Taxes - State Employment
- Workers Compensation Insurance
- Work Injury Payments
- Sick Leave
- Uniform and Tool Allowance
  - Maintenance
  - Transportation
- Longevity Award
- Benefit Trust Contribution
- Physical Damage Premium
- Casualty Claims Payments
- Workers Compensation Claims Payments
  - Station Agents
  - Maintenance
  - Other Rail Employees
- Other Insurance Premiums
- Railroad Insurance Premium
- Bodily Injury and Property Damage Premium

These projections are shown in Table 1 as the annual percentage rate of increase for each year from 1982 through 2000.

Inflation rates for bus and rail maintenance parts, supplies, and services are based on near-term WMATA budget assumptions (5 percent above the CPI rate of inflation). After five years, the incremental rate is assumed to drop to 3 percent above the CPI rate.

APPLICATION

The cost model described above has been applied to four regional transit alternatives in the course of

Figure 4. Cost equations: administration.

EXECUTIVE OFFICE
- Director and Staff
- Legal
- Internal Audit

FINANCE
- Director and Staff
- Treasury Services
  - Manager and Staff
  - Ticket and Pass
  - Cashier Operations
  - Encoding Machine Operators
  - Revenue Attendants
  - Farecards
- Accounting
- Management Information Systems
- Risk Management
  - Risk Management Staff
  - Claims Adjusters
  - Claims Chief and Staff
  - Direct Expenses
- Budget and Systems

TRANSIT SYSTEMS DEVELOPMENT
- Director and Staff
- Program Control
- Engineering and Construction Manager and Staff
- Engineering
- Construction
- Project Development
- Capital Programming
- System Planning
- Right-of-way

ADMINISTRATIVE SERVICES
- Director and Staff
- Purchasing and Stores
  - Manager and Staff
  - Warehouse and Storeroom Clerks
- Office Services
- Contracts Administration
- Grants Administration
- Human Resources
- Security
  - Officers
    - Patrol
      - Buses
      - Busways
      - Train/Station
    - Revenue Protection
  - Field Supervisors
  - Investigators
    - Bus
    - Rail
  - Administration Staff - Transit Police
  - Security Guards
    - Garages
    - Rail Yards
  - Zone Monitors
    - Park and Ride Lots
    - Stations
  - Security Supervisors
  - Administrative Staff Security
  - Direct Expenses
- General Overhead
  - Rent for Administration Building
  - Payroll Taxes
  - Non-Union Pension
  - Hospital, Surgical, Medical Plans
  - Travel

PUBLIC SERVICES
- Government and Public Affairs
- Affirmative Action
- Community Relations
- Marketing

GENERAL OPERATING COSTS
- Union Pension
- Life Insurance Plans
- Work Injury Payments
- Sick Leave
- Longevity Award
- Benefit Trust Contribution
- Workers Compensation Claims Payments
  - Maintenance
  - Administration

Figure 5. Worksheet for sample cost equation.

ALTERNATIVE BASE LINE RAIL FY2000	RAIL OPERATIONS MAINTENANCE OF WAY (Continued)		FY2000 COSTS IN 1982 DOLLARS		Peat, Marwick, Mitchell & Co. PAGE 14 OF 27
Track Maintainers	Route-Miles	x Maintainers / Route-Mile	x Avg Maintainers Wage / Main-Year		
$526,575	17.5	1.5	$20,060		
Track Foreman	(Track Maintainers)	÷ Maintainers / Foreman	x Avg Foreman Salary / Man-Year		
$135,476	23.6	6	$30,907		
Maintenance of Way Shop Repairmen	Route-Miles	x Repairman / Route-Mile	x Avg Repairman Wage / Man-Year		
$422,503	17.5	1.0	$24,143		
Maintenance of Way Shop Foreman	Foreman / Shift	x Shifts / Days x Days / Week	÷ Shifts Worked / Week	x Avg Foreman Salary / Man-Year	
$34,805	1	1 5	4.44	$30,907	
Supervisor + Staff-Wayside Equipment	Salaries (Fixed)				
$43,500	$43,500				

the financial analysis. These alternatives were defined during the travel-demand analysis and include high-capacity facilities in travel corridors with the highest peak-period volumes. In addition, the alternatives include many non-MTA facilities to be built by the Texas State Department of Highways and Public Transportation. These alternatives are

Table 1. Inflation projection: annual percentage change.

Year	Houston SMSA CPI	U.S. CPI	Houston Diesel Fuel	Houston Electricity
1983	5.8	6.9	3.4	14.7
1984	6.2	6.8	9.6	14.7
1985	6.5	7.0	13.5	14.7
1986	6.8	7.5	15.5	14.7
1987	6.6	7.2	13.7	14.7
1988	6.5	7.0	14.5	14.7
1989	6.5	6.8	14.5	14.7
1990	6.5	6.9	13.6	14.7
1991	6.3	6.7	11.7	8.4
1992	6.1	6.5	10.8	8.4
1993	6.0	6.3	10.6	8.4
1994	5.9	6.2	10.1	8.4
1995	5.9	6.1	9.6	8.4
1996	6.0	6.2	8.8	8.4
1997	5.9	6.3	8.6	8.4
1998	5.9	6.3	8.2	8.4
1999	5.9	6.3	8.3	8.4
2000	5.8	6.2	8.1	8.4

1. Base bus contains the FY2000 all-bus system with one-way busways on the North, Gulf, and Katy Freeways. Bus routes feeding these high-speed facilities are included in the regional bus system.
2. Busway contains the FY2000 all-bus system with bidirectional busways in the Priority Corridor and one-way busways on the North, Gulf, and Katy Freeways. Bus routes feeding these high-speed facilities are included in the regional bus system.
3. Baseline rail contains a rapid rail line from the West Loop, through the central business district, and out to Crosstimbers. One-way busways are on the North, Gulf, and Katy Freeways. Bus feeder routes serving the rail stations are included in the regional bus system estimates.
4. Rail-to-North Belt contains the rapid rail line from the Base Rail alternative extended past Crosstimbers to the North Belt. The addition of feeder bus service to the new stations and the consequent reduction of line-haul bus routes are reflected in the regional bus system.

Figure 6 identifies the alignment of the various transitways studied.

The travel-demand analysis determined, for each alternative, the quantity of service to be provided and the resulting patronage in each analysis year from FY1982 (the base year) through FY2000 (the design year). Table 2 presents the FY2000 system characteristics. These include both service statis-

Figure 6. Transit way corridors.

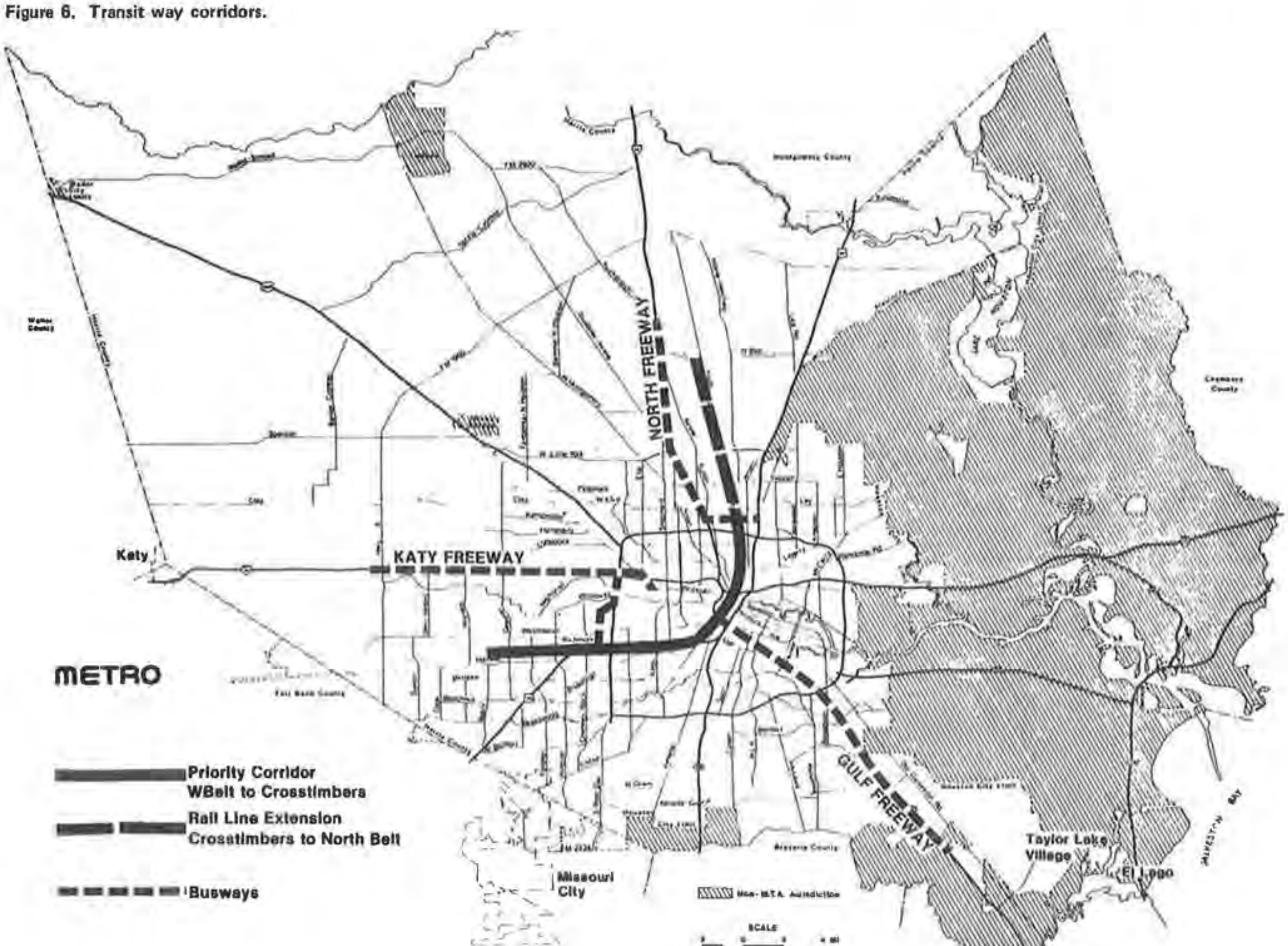

Table 2. FY2000 system characteristics.

System Characteristic	Base Bus	Busway	Base Line Rail	Rail to North Belt
Bus				
Regular buses	1885.0	1872.0	1507.0	1440.0
Articulated buses				
Total buses (peak period)	1885.0	1872.0	1507.0	1440.0
Regular bus surface vehicle miles	71.574	58.673	52.874	52.670
Regular bus guideway vehicle miles	29.609	63.253	31.761	24.670
Total regular bus vehicle miles	101.183	121.926	84.635	77.340
Articulated bus surface vehicle miles	0.0	0.0	0.0	0.0
Articulated bus guideway vehicle miles	0.0	0.0	0.0	0.0
Total articulated bus vehicle miles	0.0	0.0	0.0	0.0
Total vehicle miles (millions)	101.183	121.926	84.635	77.340
Platform hours (millions)	6.286	6.395	4.923	4.729
Operating garages	9.0	9.0	8.0	7.0
Maintenance facilities (ft^2 000 000s)	1.345	1.345	0.943	0.977
Park-and-ride lots	36.0	36.0	37.0	38.0
Service areas	13.0	13.0	13.0	13.0
Contraflow busways	0.0	0.0	0.0	0.0
Gulf freeway-type busways	3.0	3.0	4.0	3.0
Other busways	0.0	2.0	0.0	0.0
Total revenue ($000 000s)	98.406	118.018	130.191	131.157
Contract bus hours (millions)	0.0	0.0	0.0	0.0
Rail				
Peak vehicles			108.0	144.0
Peak trains			18.0	24.0
Base trains			8.0	11.0
Early/late trains			6.0	7.0
Total vehicle miles (millions)			8.728	12.518
Route miles			17.5	25.1
At-grade/elevated stations			14.0	18.0
Subway stations			3.0	3.0
Mezzanines			17.0	21.0
Service and inspection yards			1.0	1.0
Traction substations			17.0	21.0
Chiller plants			1.0	1.0
Rail passengers (millions)			85.619	86.510

Table 3. FY2000 costs by division (millions of dollars).

	Base Bus			Busway			Base Line Rail			Rail to North Belt		
Costs by Division	1982 Dollars	Inflated Dollars	1982 Dollars, No Incremental Inflation	1982 Dollars	Inflated Dollars	1982 Dollars, No Incremental Inflation	1982 Dollars	Inflated Dollars	1982 Dollars, No Incremental Inflation	1982 Dollars	Inflated Dollars	1982 Dollars, No Incremental Inflation
Director and staff	2.4	7.0	2.4	2.4	7.1	2.4	2.2	6.5	2.2	2.2	6.4	2.2
Vehicle maintenance	166.1	488.0	100.6	185.5	545.0	112.4	135.3	397.6	82.0	126.1	370.6	76.5
Facility maintenance	6.6	19.3	6.3	6.6	19.3	6.3	4.9	14.3	4.7	5.0	14.6	4.8
Transportation	94.4	277.5	94.4	96.1	282.4	96.1	74.9	220.1	74.9	71.8	211.0	71.8
Planning and scheduling	2.5	7.3	2.5	2.5	7.4	2.5	2.1	6.2	2.1	2.1	6.1	2.1
Employee development	1.0	2.9	1.0	1.0	2.9	1.0	1.0	2.9	1.0	1.0	2.9	1.0
Transportation programs	5.9	17.4	5.6	6.2	18.3	5.9	6.1	18.0	5.8	5.9	17.4	5.6
General operating costs	43.6	128.0	40.7	45.8	134.5	42.8	34.7	101.8	32.4	33.1	97.2	30.9
Bus operations total	322.4	947.5	253.5	346.0	1016.9	269.4	261.2	767.6	205.1	247.2	726.2	194.8
Director and staff							0.2	0.5	0.2	0.2	0.5	0.2
Transportation												
Superintendent and staff							0.3	1.0	0.3	0.3	1.0	0.3
Central control							0.4	1.3	0.4	0.4	1.3	0.4
Train operations							1.5	4.4	1.5	1.8	5.4	1.8
Station operations							2.4	6.9	2.4	2.9	8.5	2.9
Maintenance												
Superintendent and staff							0.1	0.2	0.1	0.1	0.2	0.1
Vehicle maintenance							6.7	19.6	4.8	9.2	27.2	6.6
Maintenance control							0.5	1.6	0.5	0.5	1.6	0.5
Maintenance-of-way							23.0	67.7	13.6	30.7	90.2	18.0
Safety and assurance							0.9	2.5	0.9	1.0	2.9	1.0
General operating costs							6.1	18.0	5.7	7.1	20.9	6.6
Rail operations total							42.1	123.6	30.4	54.3	159.6	38.5
Executive office	1.3	3.4	1.3	1.4	3.5	1.3	1.1	2.9	1.1	1.3	3.2	1.2
Finance	10.0	27.3	9.7	11.0	30.0	10.6	10.6	29.1	10.2	11.0	30.1	10.5
Transit systems development	3.7	10.9	3.6	3.7	10.9	3.6	3.7	10.9	3.6	3.7	10.9	3.6
Administrative services	20.5	58.8	19.6	21.3	61.0	20.4	20.8	60.0	20.0	20.8	59.7	19.9
Public services	4.1	10.4	3.9	4.2	10.7	4.0	3.5	9.0	3.4	3.9	9.9	3.7
General operating costs	0.3	0.9	0.3	0.3	0.9	0.3	0.3	0.8	0.3	0.3	0.8	0.3
Administration total	39.9	111.7	38.4	41.9	117.1	40.3	40.1	112.8	38.5	40.9	114.6	39.2
System total	362.5	1059.2	291.9	388.0	1134.0	309.7	343.4	1004.0	274.0	342.4	1000.4	272.5

tics (e.g., miles, hours, and vehicles) and physical characteristics (e.g., stations, yards, and garages). Based on these system characteristics, FY2000 operating costs were computed and are presented in Tables 3 and 4. Table 3 presents the costs organized by the MTA management hierarchy. This presentation is useful in comparing future costs with current budgeted MTA operating costs. Table 4 presents the costs arranged by category, or object class. This presentation is useful in exploring cost components of special interest to management (e.g., union wages, diesel fuel) or to investigate inflation effects in sensitivity analyses.

Three values of cost are presented for each alternative in Tables 3 and 4. They involve the following considerations of inflation:

1. 1982 dollars. Costs are computed by using the inflation rates defined above, and then they are deflated on the basis of the Houston CPI alone. These costs, therefore, include the incremental effect of those cost components that inflate at a rate

Table 4. FY2000 costs by category (millions of dollars).

	Base Bus			Busway			Base Line Rail			Rail to North Belt		
Costs by Category	1982 Dollars	Inflated Dollars	1982 Dollars, No Incremental Inflation	1982 Dollars	Inflated Dollars	1982 Dollars, No Incremental Inflation	1982 Dollars	Inflated Dollars	1982 Dollars, No Incremental Inflation	1982 Dollars	Inflated Dollars	1982 Dollars, No Incremental Inflation
Operator/station agent	89.2	262.3	89.2	90.8	266.8	90.8	72.7	213.5	72.7	70.6	207.6	70.6
Repairmen/maintainer/cleaner	26.7	78.3	26.7	29.1	85.4	29.1	27.8	81.6	27.8	28.7	84.5	28.7
Other	4.3	12.6	4.3	4.5	13.2	4.5	4.0	11.6	4.0	3.5	10.4	3.5
Total wages	120.2	353.2	120.2	124.4	365.4	124.4	104.4	306.8	104.4	102.9	302.5	102.9
Front-line supervisors	5.6	16.4	5.6	6.0	17.7	6.0	7.4	21.8	7.4	7.8	22.8	7.8
Other	27.2	77.1	27.1	28.3	80.0	28.2	29.0	82.6	28.9	29.2	83.2	29.2
Total salaries	32.8	93.5	32.7	34.3	97.7	34.2	36.4	104.5	36.3	37.0	106.0	36.9
Total wages and salaries	153.0	446.8	152.9	158.6	463.2	158.6	140.8	411.2	140.7	139.9	408.5	139.8
Fringe benefits	28.4	83.2	26.6	29.5	86.2	27.6	25.9	75.7	24.2	25.7	75.1	24.0
Diesel fuel	62.3	183.0	29.4	64.1	188.5	30.3	49.3	145.0	23.3	46.8	137.5	22.1
Bus utilities	1.7	5.0	1.6	1.7	5.0	1.6	1.2	3.5	1.1	1.2	3.6	1.1
Rail electricity	0.0	0.0	0.0	0.0	0.0	0.0	13.8	40.5	6.0	18.8	55.4	8.3
Total fuel and utilities	64.0	188.0	31.0	65.8	193.5	31.9	64.3	189.0	30.5	66.9	196.5	31.5
Vehicle maintenance Parts, supplies, and services	72.5	213.1	40.1	87.3	256.7	48.3	64.8	190.4	35.8	61.4	180.4	34.0
Other maintenance Parts, supplies, and services	3.2	9.4	3.0	3.3	9.7	3.1	6.1	17.8	4.3	7.0	20.7	4.8
Other direct expenses	17.7	49.5	16.3	18.3	51.3	17.0	17.3	48.8	16.0	17.6	49.5	16.3
Purchased transportation	3.6	10.5	3.3	3.6	10.5	3.3	3.6	10.5	3.3	3.6	10.5	3.3
Total parts, supplies, and services	96.9	282.5	62.7	112.5	328.2	71.6	91.8	267.5	59.4	89.6	261.0	58.3
Insurance	6.7	19.8	6.2	7.7	22.7	7.2	8.7	25.5	8.0	8.4	24.8	7.8
Taxes	13.3	39.0	12.5	13.8	40.3	12.9	12.0	35.0	11.2	11.8	34.6	11.1
Total operating costs	362.3	1059.2	291.9	388.0	1134.0	309.7	343.4	1004.0	274.0	342.4	1000.4	272.5

Table 5. FY2000 number of employees.

	Base Bus		Busway		Base Line Rail		Rail to North Belt	
Computed Employees	Union	Non-Union	Union	Non-Union	Union	Non-Union	Union	Non-Union
Bus operations								
Operators/supervisors	4040	80	4110	84	3167	82	3042	80
Vehicle mechanics, cleaners/foremen	1015	93	1115	103	815	75	770	71
Facilities repairmen, cleaners, foremen	133	9	133	9	99	7	101	7
Other	185	267	195	267	163	254	147	246
Subtotal	5374	450	5553	464	4244	418	4060	404
Rail operations								
Operators/supervisors	0	0	0	0	50	14	66	14
Station agents/supervisors	0	0	0	0	80	20	99	25
Vehicle repairmen, cleaners, foremen	0	0	0	0	87	9	117	12
Maintenance-of-way repairmen, foremen	0	0	0	0	195	34	253	44
Other	0	0	0	0	6	92	6	98
Subtotal	0	0	0	0	419	169	542	192
Executive office	0	8	0	8	0	8	0	8
Finance	0	214	0	236	0	217	0	226
Transit systems development	0	77	0	77	0	77	0	77
Administrative services								
Security	0	292	0	306	0	303	0	293
Other	27	169	27	170	24	159	21	166
Subtotal	27	461	27	481	24	461	21	459
Public services	0	68	0	70	0	59	0	64
Total employees	5401	1278	5580	1337	4687	1409	4623	1431

different from that of the Houston CPI.

2. Inflated dollars. Costs are computed by using the inflation rates defined in Table 1. These costs, deflated by the Houston CPI, equal the 1982 dollar costs.

3. 1982 dollars, no incremental inflation. Costs include no inflation whatsoever and are based solely on the FY1982 base year unit costs, wages, and salaries. These costs can be considered as the costs to operate the FY2000 systems in 1982. Thus, these costs can be useful in comparing the model results with current transit industry experience (7).

Table 5 presents FY2000 employees for each alternative. These values are determined during the course of the cost model computations and are useful in explaining some of the differences in costs. In addition, they can provide guidance to management in the consideration of service expansion plans.

CONCLUSION

The transit operating cost model presented in this paper has several important features that make it a useful analytical tool for transit management. First, the model is rich in detail, capturing the cost effects of staffing levels, labor productivity standards, unit prices, and inflation for different cost components. Second, the model is user-oriented. It is formulated on the basis of data commonly developed in the budgeting process. Its responsibility center-based organization provides for both ease in comparing projections with current conditions and ease in updating various data values. Finally, the model can be applied either manually or on a computer. Simplified worksheets allow for organized computation. Both mainframe and microcomputer applications have been successfully performed.

There are fundamentally two potential applications of the cost model. For short-range planning, the model can be used in the budgeting process for quick-response sketch planning. It could be used in many of the what-if questions typically asked by management regarding the cost effects of alternative service changes or potential labor productivity changes. It can also be useful in the context of sensitivity analyses concerning rates of inflation or other unknowns.

In long-range planning, the model can apply current and anticipated cost experience to project operating costs in the financial and cost-benefit analysis of major capital investments. The cost model described in this paper provides a strong analytical foundation for multiyear analysis of transit investment in Houston, Texas. Other such applications should certainly be possible.

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Tri-Met Bus Operator Costing Methodology

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Traditional financial planning techniques are rapidly becoming inadequate as public mass transit confronts an environment characterized by limited and fluctuating revenues, funding shortfalls, and rising costs. The Tri-Met operator costing model is a part of a financial forecasting system approach toward the planning process in which short- and long-term consequences of alternative operating policies and performance can be determined. Tri-Met has drawn on past experience, research and review of existing methodologies, and future needs assessments to develop a costing methodology that combines the positive features of cost build-up and historical cost approaches and represents a sensitivity to the causal relationships underlying fixed and variable cost items at a marginal cost level. Bus operator costs are projected on a monthly basis over a six-year time frame as a function of service levels, service characteristics, work rules, productivity, and economic conditions. Common applications of the model range from service and scheduling changes to union labor contract provisions, assessments of part-time drivers, benefits, productivity, and absenteeism. The forecast technique has proved to be an invaluable tool of cost management and control, minimizing the risks involved in critical policy decisions.

Traditional financial planning techniques were sufficient tools of cost-revenue management when costs remained relatively stable and revenues were predictable and even sufficiently available. But growing complexities that characterize today's financial policy decisions require sophistication in planning, anticipating, and coping with financial uncertainties. Transit planning is increasingly complex due to demands to apply new and better tools for handling the dynamics of limited and fluctuating revenues, funding shortfalls, and rising costs. As a result, transit operators are directing greater attention toward cost effectiveness, efficiency and control, productivity, and performance analysis. It is fundamental to the responsibilities of transit operators to not only manage existing revenues and